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ABSTRACT

This paper describes a study designed to investigate the development of scientific reasoning or logical thinking patterns of South Korean secodary school students. The scientific reasoning or logical thinking patterns were categorized into patterns of logic such as seriation, combinations, proportion, control of variables, probability, and proposition. The investigation intended to determine when South Korean secondary school students use the scientific thinking patterns in problem-solving situations and to identify the level of intellectual development which the students reach in terms of Piagetian developmental stages. The conclusions reached as a result of the study include: (1) the formal thinking variables of combination and two-dimensional reasoning develop relatively early, while proposition and probability develop comparatively late; and (2) the cognitive development level of South Korean secondary students in this study did not coincide with Piaget's prediction, but displayed similar results to some earlier studies. Additional results related to student variables including geographical location, sex, and socio-economic status are also reported. (TW)

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THE COGNITIVE DEVELOPMENT OF SECONDARY SCHOOL STUDENTS IN THE REPUBLIC OF KOREA

September 14-20, 1986

Korean Educational Development Institute, Seoul, Korea

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The Cognitive Development of Secondary School Students in the Republic of Korea*

by

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U.S.-Japan Seminar on Science Education Sponsored
by the National Science Foundation and the
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I. Introduction

The purpose of the study was to investigate the development of scientific reasoning or logical thinking patterns of Korean secondary school students. Scientific reasoning or logical thinking patterns which had been dealt with in this study were categorized into seven patterns of logic such as seriation, combinations, proportion, control of variables, probability, proposition. According to Piaget (1971) these scientific reasoning patterns could be formed and used by 12 to 16 year old students who reached the level of formal operational stage. The age of 12 to 16 years corresponds to the secondary school level. In contrast to Piaget's findings, however, other research findings (Raven, 1971; Lawson, 1973; Karplus, 1969; Han, 1977) reveal that the majority of students of that age can not use such scientific reasoning to solve the given problems. These findings also suggest that most students at this age do not reach the level of formal operational thinking.

Therefore, the primary concerns of this study were to find out when Korean secondary school students use the scientific thinking patterns in problem-solving situations and to identify the level of intellectual development which the students reach in terms of piagetian developmental stages.

The subjects used in this study were the first, second, and third graders of the middle school, about 3,164 and the first and second graders of the high school, about 1,981, across the country. They were selected by using the stratified cluster sampling technique with respect to sex and regional area which was then categorized into big city and rural or coastal area.

*"This is a part of research report titled" A Study of the Development of Cognitive and Affective Characteristics of Korean Secondary School Student (1983) carried out by J.H. Han, et al. This article does not include some parts of the data in the orginal report.

In order to identify the level of intellectual development as well as patterns of scientific thinking, the researcher reproduced three instruments. These were "How is your logic?" developed by W.M. Gray and BSCS committee, and "The Ratio Puzzle" and "Control of variables" developed by R. Karplus of the University of California, Berkeley, U.S.A.

II. Literature Review

A. Piaget's Cognitive Development Theory

The theories of Piaget, the Swiss development psychologist, are the most inclusive and penetrating in the field of study on the formation of children's and adolescents' knowledge and the developmental stages of intelligence.

According to Piaget's cognitive development theory, children's intelligence goes through several stages before it reaches the adult level. For example, we might mention propositional thinking and hypothetio-deductive thinking as characteristics particular to adult intelligence. According to Piaget's theory, these logical modes of thinking are explained as intelligence characteristics which are not formed until the formal operational stage of development (Innelder & Piaget, 1958). Piaget's assertion is that these intelligence characteristics are completed through several stages of qualitative change (Piaget & Inhelder, 1969).

Piaget's theory of cognitive development is divided into four stages. The first stage, from birth to age 2, he calls the sensorimotor intelligence stage. Human beings must pass through this stage without benefit of the abilities of the adult intelligence. In other words, adult hypothetico-deductive thinking develops from the primitive starting point of this sensorimotor stage. An intellectual characteristic of this stage is that understanding and adaptation are achieved solely through sensorimotor functions; without any adult thinking they are able to adapt to their circumstances. As a result, sensorimotor functioning at this stage is extremely acute and active. During the latter half of the stage-with the development of language-the intellectual characteristics take on a new dimension.

The second stage, from 2 to 6 years of age, is the pre-operational thinking stage. At this stage, with rapidly increasing active use of language, children communicate very differently than they did in the former stage and, within restrictions, they begin including primitive logic which was not found in the previous stage. At this point primitive logic is characteristically intuitive. Children of this stage are unable to explain the process of their logic yet they are able to get certain answers to their questions. Piaget therefore sometimes called this stage of thinking in 4-5 year old children, the intuitive thinking stage (Piaget & Inhelder, 1969).

Piaget labelled these intellectual characteristics as pre-operational thinking. In this instance, operation, as used by Piaget, means intellectual action. Piaget described intellectual operation as being composed of several intellectual actions. For example, it includes what is defined as a concept of reversible thinking or compensational thinking. In this case, the term "reversible thinking" means the ability to explain the details of a case with logical inevitability. For example, the same amount of juice in two cups of the same size (A and B) are shown to a child. With the child looking on, one of the two cups of juice (A) is emptied into a cup of different shape and size (C). Then the subject is asked to compare the amount of juice in the other cup (B) and the different cup (C). If the subject has the capacity of reversible thinking, he will answer that they contain the same amount of juice. That indicates that he recognized the conservation of quantity of substance. But if the subject is incapable of reversible thinking he will reply that the cups have different quantities of juice. Piaget regarded the intellectual characteristic of a child without reversible thinking as "pre-operational."

In fact, this pre-operational intelligence might be regarded as a precursor of the adult's logical thinking, and might thus be called "primitive logical thinking." As the latter half of this stage is reached however, children begin to display characteristics which indicate a major intellectual change.

The third stage is known as the concrete operational thinking stage. This stage, spanning ages 7-12, represents a major qualitative change in the child's cognitive development.

The intellectual characteristic of this stage is reversible thinking. As we have noted above, the experiment in recognizing the conservation of quantities of materials shows the characteristics of reversible thinking. Children at this stage are able to recognize logical inevitability as exemplified in the experiment, i.e., even though the containers are changed unless we add or reduce the materials, the original quantity remains the same. This logical judgement is the same as the adult's. From this stage children begin to command the same characteristic as adult logical thinking. The child now is able to make use of adult logical processes such as the logical connection between cause and effect, the relation of two variables and the recognition of all possibilities for a certain case.

But a characteristic of this stage is that, even though adult logical thinking is now available, it functions only within a limited range and under limited conditions. In order to reach the adult stage there is still, therefore, another stage to go through , since reversible thinking, or the logical relation of cause and effect, can now occur only under concrete circumstances (Piaget, 1971).

Logical judgement and thinking for children at the concrete

operational stage become unreal under abstract or formal conditions which cannot be perceived by sensory functions. What this means is that hypothetico-deductive reasoning is beyond their capabilities, and also that for children at this stage, propositional thinking is also impossible.

But Piaget stated in his theory that toward the end of this stage-around the age of 12 - abstract thinking similar to the adult level begins to develop. In other words, at this stage qualitatively changed intellectual characteristics begin to emerge. Piaget classified this as the formal operational thinking stage.

This fourth stage of formal operational thinking prevails during the years from 12 to 16. Adolescents of this period can be said to have reached the adult stage of thinking. They possess the same intellectual characteristics of adults. They are capable of hypothetico-deductive thinking, can use formal or abstract conditions and command propositional logic (Inhelder & Piaget, 1958).

Piaget enumerated conservation of quantity and volume, the logic or concept of proportion, the logic of probability and combination, separation or control of variables, proposition formation and hypothetico-deductive reasoning as the characteristics of thinking during this stage. These kinds of thinking can be regarded as the characteristics of adult thinking.

B. Rate of Cognitive Development of Adolescents

Piaget's theory of intellectual development, which we have just discussed, can be summarized by several general characteristics. First of all, children's cognitive development takes considerable time. It takes more that 12 years to arrive at the beginning of the adult stage of logical thinking - that is, six years to move from the sensorimotor stage to the pre-operational thinking stage, and more than another six years to reach the stage of adult intellect. These twelve years coincide with the time required to finish the elementary school education. Next, the stages of congnitive development are of a continuous nature. They cannot be cut short, nor can a prior stage come after a following one. The stages also have a certain character of connection. When the intellectual characteristics of one stage reach the next, they are qualitatively changed , while fundamentally they retain characteristics of the former stage (Piaget, 1970). In other words, intellect develops genetically. Piaget maintained that , in a sense, intellect develops through a process of eveolution.

Finally, any stage of this cognitive development can be easily classified by means of investigating the characteristics of that stage. For example, logic of proportion or of conservation of quantity can be investigated. As a result of this characteristic, Piaget's theory of developmental stages has

been repeatedly investigated throughout the world.

While opinions challenging Piaget's theories have rarely appeared, many studies have demonstrated that a particular stage of development and the age range presented by Piaget for that stage, differ in reality.

Results of these studies have shown that while 15 or 16 year old adolescents are supposed to show formal operational thinking, this is often not the case. According to Renner's study (1971), less than 20 percent of 17 or 18 year old college students show cognitive characteristics of the formal operational stage. Lawson (1973), Karplus (1970), Appel (1977) and other investigators have found similar results in their studies. When 300 Korean middle school students were investigated, it was found that less than 10 percent of the students (median age 14.7 years) had reached the stage of formal operational thinking (Han Jong-ha, 1977). The results of this investigation cannot be said to indicate a general tendency, since it was not carried out on a nation-wide scale. But when considered along with foreign studies, it is clear that there is a large gap between Piaget's developmental stages and his predicted age ranges.

Most of all, what these studies show is that the cognitive development of children and adolescents has a great deal of individual differences. For example, the fact that an individual has reached the age of 16 is no guarantee that he has reached the stage of formal operations which is the predicted intellectual stage for that age. As we have already indicated, there is a great difference between individuals in the time it takes to attain a specific level of intellectual development.

Therefore, if we accept Piaget's theory of cognitive development in its totality and apply it to our educational postures, there is a very real possibility of creating considerable alienation. For example, if we expect, let us say a 12 year old child to be capable of formal operational thinking due to the results of Piaget's work, and based on this assumption we plan a curriculum and select materials, there is every possibility that harmful effects will arise.

III. Results

1. Logical Thinking

A. General Tendencies of Logical Thinking Development

1. Tendency by Age and Grade

Thirteen items of the logical development test are composed of five factors which represent the types of logical thought: proposition, probability, combination, controling variables and seriation. We excluded items for measurement of seriation from the results of the test because all the students answered them

correctly,[1] which indicates middle and high school students have already passed the early stage of concrete operation. In interpreting the results of logic development, it was decided that 2 points (perfect score) for each type of logic indicates complete establishments of that type, approximately 1 point indicates the transitional period of establishment, and under 0.5 points indicates it is unestablished. As a result of the logic development test, mean and standard deviation and F ratio the primary variable of age appears as shown in Table 1.

According to Table 1, proposition, probability, combination and controling variables display increased development with increased age ($P < .001$). Propositional logic and probability, out of the primary variables, showed the lowest score among 12, 13 and 14 year olds (0.21=0.48). Even at the age of 15 or 16, its development is generally low. On the other hand, in the case of combination and controlling variables, at the ages of 12, 13 and 14, students are in the transitional period of establishment (0.71-1.04) and even at the age of 15 or 16 do not exceed that period (1.09-1.43).

From these results, we conclude that of the formal thinking variables of combination and two-dimensional reasoning develop relatively early, while propostion and probability development comparatively late.[2]

As we see in Table 1, test scores in proposition, probability, combination and controling variables tend to increase with school years ($P < .001$). As with the tendency towards development with age, the establishment of combination and controling variables is earlier than that of proposition and probability in relation to school year (grade). In the third year of middle school, proposition and probability are for the most part unestablished, while combination and controling variables are near the transitional period of establishment. In the second year of high school, controling variables reasoning tends to be completely established, and probability and combination are in the transitional period and proposition generally unestablished.

1) The, actual results of the test showed one or two failures, but these were regarded as measurement errors in the group test and the actual establishment of seriation would need to be established by individual testing. We assumed that normal middle and high school students have obtained the concept of seriation.

2) For an analysis to determine the percentage of students capable of logical thinking refer to "Research Report on the Development of Scientific Thinking of Elementary and Middle School Students" (1982), reported by the Scientific education laboratory of this institute.

2) Tendency by Region

From the results shown in Table 2, the regional difference of each primary variable of logic development proves to be significant. In the case of middle and high school students from large cities, development of all four types of logic is comparatively faster than it is in the middle and small cities or rural areas. On the other hand, in comparison with in large cities rural areas show a reasonable difference. The results indicate that social factors influence cognitive development.

3) Tendency by Sex

The difference in logic development by sex is reported in Table 3. In proposition, the level of development of female students (0.54) tends to be higher than that of males (0.45) ($P<.001$). In the formation of the concepts of combination and controling variables the males are superior to the females. Generalizing from these results, we conclude that during the period of development of logic that is a difference between males and females according to the type of logic.

4) Tendency of Socio-Economic Status (SES)

The difference in logic development according to SES can be seen in Table 4. According to the results shown, it appears that the higher the SES, the higher the level of formation of the concepts of proposition, probability, combination and controling variables reasoning ($P<.001$). For the concepts of combination and controling variables even when SES is low, transitional characteristics of formation are evident. On the contrary, in the case of proposition and probability, if SES is low, level of formation of the concepts is also relatively low. The results here suggest tht environmental factors have a reasonable influence on the formation of logical thinking.

B. Stage pf Cognitive Development

1) Stage of Cognitive Development by Age

After analyzing the scores of the test of logic development, the results were used to create a diagram of cognitive development by age based on Piaget's stages of cognitive development. This is represented in Table 5. From these results we find that most students remain in the concrete operational stage, at the age of 12, the data shows that of "599" students, 64.6% are in the late concrete operational stage, while 35.1% have reached the early formal operational stage. At the ages of 13 and 14, the ratio of students at the late concrete operational stage to those at the early formal operational stage is approximately equal. At the ages of 15 and 16 we now find 70% of the students have reached the early formal operational stage, although those who have achieved the late formal stage comprise only 1.3%.

Piaget claimed that 7 year old children are at the concrete operational stage and 12 year olds have reached the early formal operational stage. This would mean that middle and high school students, who are from 14 to 18 years of age, could be assumed to be in the later formal operational stage. But the results of many studies that have measured secondary school students on the basis of Piaget's theory (Lawson and Renner, 1974; Hi gins-Trenk and Gaife, 1971; Pale, 1970; Karplus and Karplus, 1970; Karplus et al, 1975; Han Jong-ha, 1977; Renner et al, 1977) show that most middle and high school students do not reach the formal operational stage but remain at the concrete operational level. The cognitive development level of Korean secondary students in this research also does not coincide with Piaget's predictions but displays similar results to the studies cited above.

2) Stage of Cognitive Development by Grade

According to the results of the test of logic development, the level of cognitive development of middle and high school students according to grade is as given in Table 6. The results show that students in the first year of middle school, 69.8% are in the late concrete stage, 30.1% have reached the early formal stage and 0.1% the late formal stage. In other words, most first-year middle school students are in the concrete operational stage and display characteristic thinking of that level. In the case of second and third-year middle school students, the percentage figure for students who have reached the early formal operational stage is 49.6%. and 52.1% respectively, which demonstrates that the number of students at the formal operational stage tends to increase with school year. Even so, approximately half of the students still remain at the late concrete stage. In the case of first and second-year high school students, 76.1% of first-year and 77.5% of second-year students have reached the early formal operational stage, so it appears most students have reached this level by high school. But only 2.3% of first year high school students and 0.8% of second year high school students have reached the late formal stage, while 21.6% of first year students and 21.7% of second year students still remain at the late concrete operational stage. These results seem to agree with those of foreign studies. Lawson and Renner (1970), who administered Piaget's test to middle and high school students in Oklahoma, found that 83% of 7th, 77% of 8th, 73% of 9th, 71.1% of 11th and 66% of 12th year students had not attained the formal operational level of thinking. In Oklahoma high schools, 57.1% of the students were at the concrete level and less than 11% had reached the late formal operational stage. In comparison with these foreign studies, it appears that the percentage of Korean students who have reached the early formal operational stage is comparatively high, while the percentage reaching the late formal operational level is comparatively low. But the results of both the foreign research and this study are relatively lower than Piaget's predicted cognitive levels for school year, and also they are in agreement that the majority of adolescents do not reach formal

thinking levels until the of 16 or the latter half of the teenage years.

4) Stage of Congnitive Development by Age and Region

The variation in cognitive development in secondary school students by age and region in shown in Table 8. As in cognitive development by school year and region, development here varies with age and region. In the case of 12, 13 and 14 year old students from middle and small cities and rural areas, we find they have all reached a similar level of cognitive development, but comparison to students from large cities points out a serious gap. The data shows that by the ages of 15 and 16, this gap has become very narrow. This phenomenon appears to be due to the influence of data collected from high schools in middle and small cities where students entered unequalized by entrance exam. This also explained why there are more 15 and 16 year old students at the late formal operational stage from middle and small cities than from large cities.

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Table 1. Mean Scores of Logic Tests Tests with Different Grades

Grade \ Logic		Proposition	Probability	Combination	Controling Variables
1st yr of Mid. school N = 942	M	0.28	0.18	0.65	0.76
	SD	0.43	0.48	0.52	0.91
2nd yr of Mid. school N = 961	M	0.41	0.25	0.78	0.95
	SD	0.55	0.55	0.53	0.94
3rd yr of Mid. school N = 979	M	0.46	0.40	0.89	0.96
	SD	0.57	0.67	0.54	0.94
1st yr of high school N = 952	M	0.68	0.70	1.19	1.38
	SD	0.68	0.82	0.50	0.87
2nd yr of High school N = 968	M	0.65	0.71	1.10	1.47
	SD	0.61	0.85	0.56	0.84
All N = 4,802	M	0.50	0.45	0.92	1.10
	SD	0.57	0.67	0.53	0.90
F		101.9	137.9	22.5	147.5
P		.000	.000	.000	.000

Table 2. Means Scores of Logic Tests with Different Regions

Region \ Logic		Proposition	Probability	Combination	Controling Variables
Large cities N = 1,704	M	0.58	0.55	1.00	1.23
	SD	0.63	0.84	0.56	0.94
Middle & small cities N = 1,560	M	0.52	0.50	0.96	1.10
	SD	0.64	0.80	0.64	0.96
Rural areas N = 1,598	M	0.41	0.28	0.78	0.98
	SD	0.56	0.61	0.55	0.96
All N = 4,802	M	0.50	0.44	0.91	1.11
	SD	0.61	0.75	0.58	0.95
F		44.8	63.4	83.8	48.5
P		.000	.000	.000	.000

Table 3. Mean Scores of Logic Tests with Different Sexes

Sex \ Logic		Proposition	Probability	Combination	Controling Variables
Male	M	0.45	0.59	0.98	1.12
N = 2,125	SD	0.58	0.83	0.56	0.95
Female	M	0.54	0.32	0.86	1.10
N = 2,677	SD	0.63	0.64	0.59	0.95
Total	M	0.50	00.46	0.92	1.11
N = 4,802	SD	0.61	0.74	0.58	0.95
F		67.2	110.9	7.6	5.8
P		.000	.000	.006	.016

Table 4. Mean Scores of Logic Tests with Different SES

SES \ Logic		Proposition	Probability	Combination	Controling Variables
Low	M	0.39	0.32	0.79	0.96
N = 886	SD	0.56	0.65	0.57	0.96
Middle-low	M	0.48	0.39	0.87	1.08
N = 1,410	SD	0.61	0.71	0.57	0.96
Middle-high	M	0.54	0.50	0.97	1.16
N = 1,337	SD	0.62	0.79	0.59	0.95
High	M	0.58	0.54	1.01	1.22
N = 899	SD	0.65	0 84	0.60	0.94
All	M	0.50	0.44	0.91	1.11
N = 4,532	SD	0.61	0.75	0.58	0.95
F		19.1	19.1	28.4	10.7
P		.000	.000	.000	.000

Table 5. Precents of Students to the Cognitive Development Stage by Age

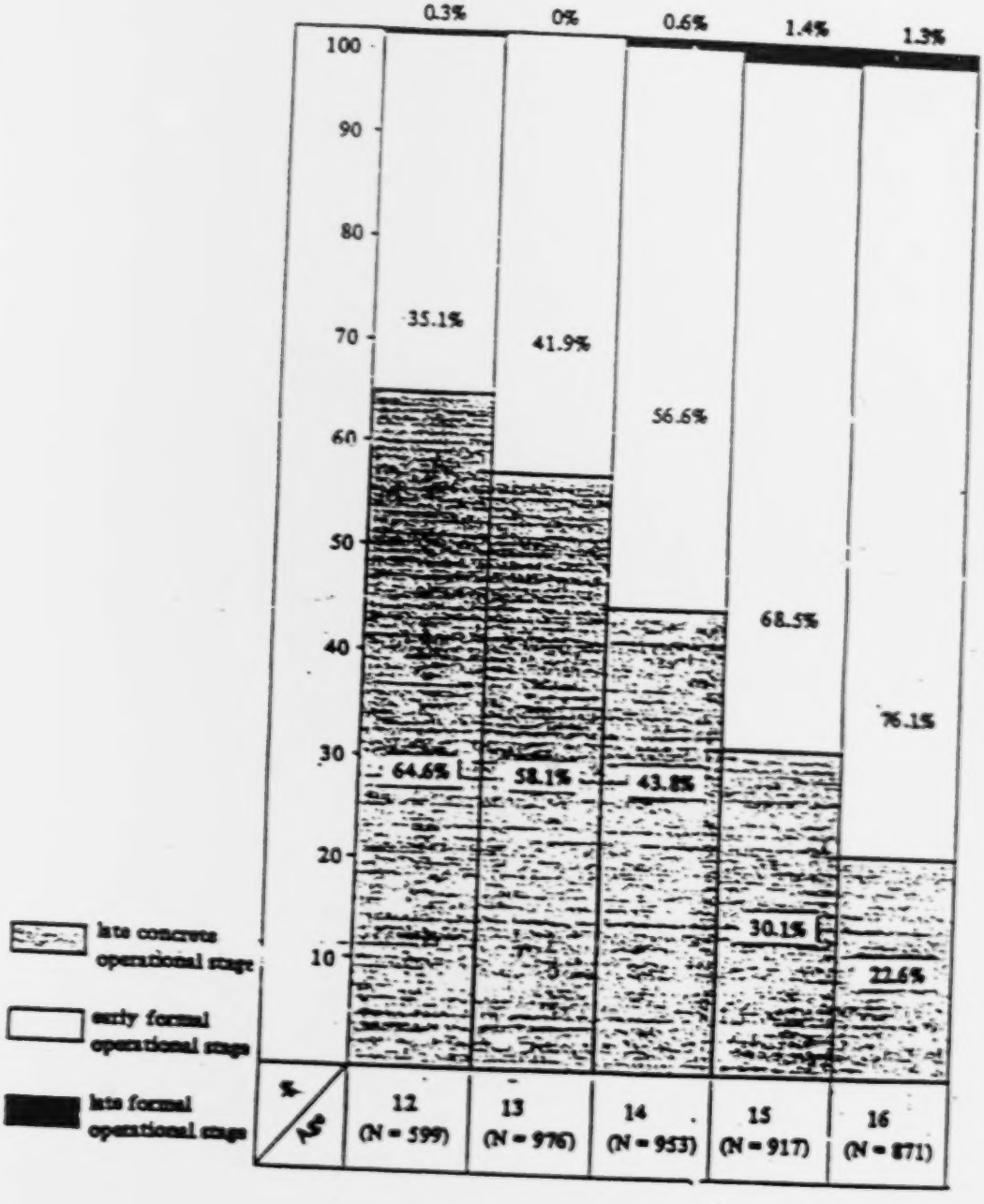

Table 6. Precents of students to the Cognitive Development Stage by Grade

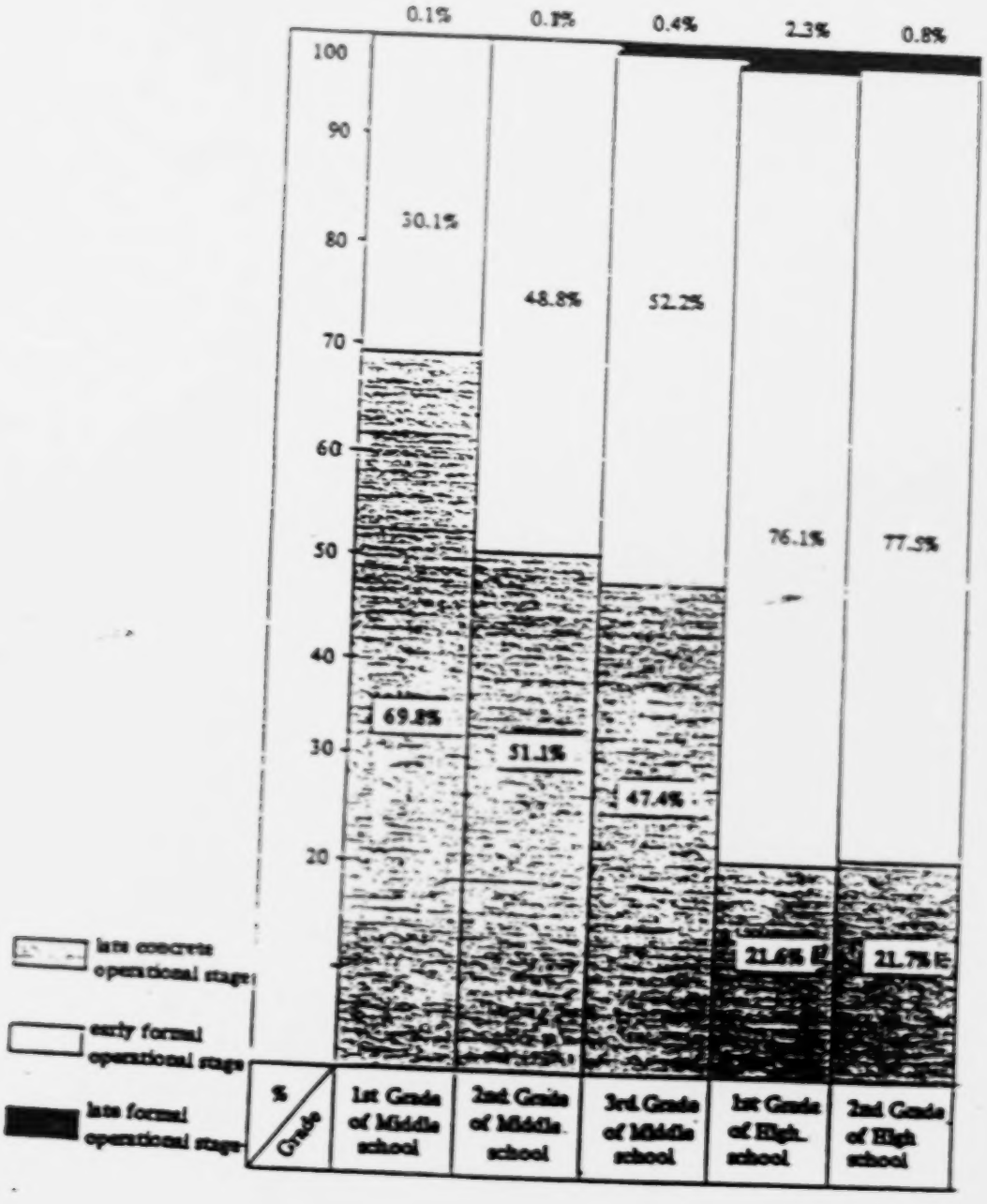

Table 7. Precents of Students to the Cognitive Development Stage by Grade and Region

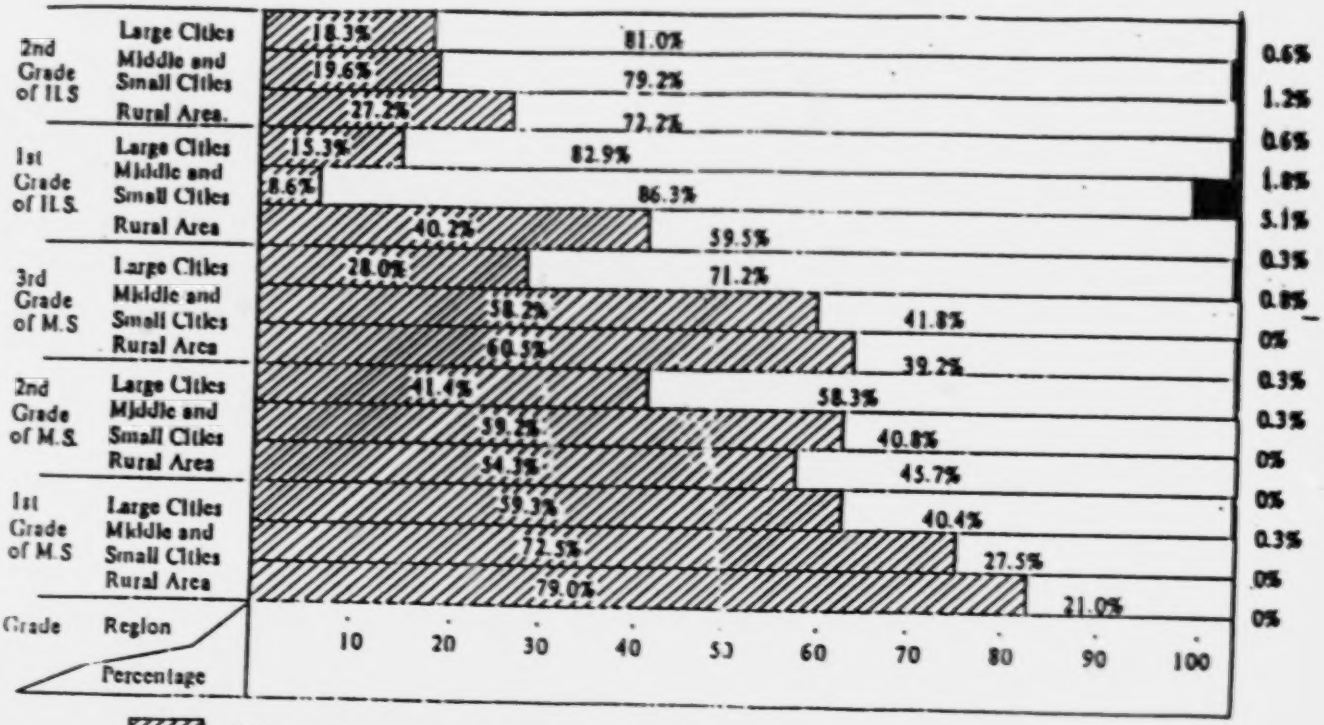

Table 8. Precents of Students to the Cognitive Development Stage by Age and Region